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TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 750

INFLUENCE OF CUT-OUTS IN ELEVATOR ON THE STATIC LONGITUDINAL STABILITY AND ON THE STATIC ELEVATOR EFFECT

By Curt Biechteler

Luftfahrtforschung, Vol. 11, No.1, May 15, 1934

Washington
August 1934

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INFLUENCE OF CUT-OUTS IN ELEVATOR ON THE STATIC LONGITUDINAL STABILITY AND ON THE STATIC ELEVATOR EFFECT*

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SUMMARY

The rudder effect of a sport airplane at high angles of attack was to be improved. This made it necessary to make a cut-out in the center of the continuous elevator so as to enlarge the rudder downward. This cut-out which reduced the rudder area by 12.5 percent changed the static stability of the airplane as well as the elevator effect. Flight measurements showed the stability zone with locked elevator to be 1.8 percent less at full throttle and at idling to be 1.3 percent less than the mean wing chord. The effect of the cut-out on the control forces could not be determined owing to insufficient instrumental accuracy at the extremely low existing forces. The measurement of the static controllability resulting from the cut-out manifested an 18 percent drop in elevator effect at full throttle and a 10 to 20 percent drop at idling, depending on the lift.

INTRODUCTION

The airplane shown in figure 1 had a poor rudder effect at high angles of attack. The fuselage tapers to a horizontal knife edge which terminates in a continuous elevator with the rudder above it (fig. 3). The poor rudder effect is due to its being partially blanketed by the one-piece horizontal tail surface at high angles of attack.

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*"Einfluss eines Ausschnittes im Höhenruder auf die statische Längsstabilität und die statische Höhenruderwirkung." Luftfahrtforschung, Vol. 11, No. 1, May 15, 1934, pp. 1-4.

The improvements consisted in making a cut-out in the middle of the elevator, which reduced its area by 12.5 percent (fig. 2). The rudder hinge was set to the rear thus deepening the fin. The rudder was enlarged so as to extend below the elevator surface, and the height of the vertical fin reduced by 16 cm to avoid stiffening of the fin attachment fittings (fig. 4).

In order to determine the effect of the modified vertical tail surfaces on the rudder we measured the elevator deflection necessary for level flight at full throttle and idling with respect to the dynamic pressure. Previous experiments of this kind on the Junkers A 35 (reference 1) already manifested a certain scatter of the test points. It was found that minor aileron displacements scarcely perceptible to the pilot himself, had a profound effect on the magnitude of the rudder deflections. The examined airplane (type BFW M 23b) had an even better aileron effect than the A 35, so that this effect was even more pronounced. The results of the flight tests showed the scatter of the test points to be within the limits in which any improved rudder effect through enlargement of the tail surface could be anticipated.

The investigation thus narrowed down to the qualitative valuation by several pilots. The airplane was flown by three pilots of the DVL, and they were unanimous in their claim of better rudder effect especially at high angles of attack.

The cut-out in the elevator modified the elevator effect, and the purpose of this report is to determine the effect of this cut-out on the static longitudinal stability, the elevator forces and the static elevator action.

TEST PROCEDURE

The particular airplane was fitted with the instruments necessary for recording the dynamic pressure, the elevator setting, the stick force, the altitude and pitching of the airplane. The measurements were effected in unaccelerated flight for four different c.g. positions of the airplane. The method was the same as in previous tests. The first series pertained to measurements with the original, the second with the modified elevator.

RESULTS OF TESTS

Effect of cut-out in elevator on static longitudinal stability.- The evaluation of the data gave the lift coefficient versus elevator setting shown in figures 5 and 6. Figure 5 gives the curves for full throttle, figure 6, for idling at four different c.g. positions with elevator cut-out. The slope of the curves, that is $\frac{\delta \beta}{\delta c_a}$, reveals instability for c.p. positions r_3 and r_4 and stability for r_1 and r_2. The trend of the curves in the upper range shows that at full throttle only minor elevator deflections are needed to produce great lift changes in contrast to the very great deflections necessary at idling. Consequently, the response of the elevator increases at full throttle as the lift increases and decreases at idling.

In order to determine the neutrally stable c.g. position we defined the moment coefficient c_m relative to the lift coefficient c_a and plotted the slope of this straight line against the c.g. position (figs. 7a, b, and 8a, b). According to previous test data (referemce 2) the change of stability with elevator locked is linear with the c.g. position at full throttle and idling, in fact, these straights have the same slope for all airplanes investigated heretofore. We also included the c.g. position versus the slope of the elevator deflection curves for $c_a = 0.4$. Comparison of the test data, (figs. 7 and 8) manifests a drop in longitudinal stability as anticipated: the neutrally stable c.g. position at full throttle was reduced by 1.8 percent of the mean chord (from 35.4 to 33.6) and at idling by 1.3 percent (from 37.0 to 35.7).

Figure 9 shows the recorded control force against the dynamic pressure for four different c.g. positions at idling and at full throttle. The curves are straight up to $q \sim 70$ kg/m². The slope of the straight, i.e., value $\frac{\delta P}{\delta q}$, changes with the c.g. of the airplane. The slope is less as the c.g. moves backward. The control force is not affected by the cut-out in the elevator as far as could be observed, because of the very small recorded control forces the anticipated change (about 10 percent = 0.1 to 0.2 kg) remained within instrumental accuracy.

The result of the pitching records is shown in figure

10, as lift coefficient versus angle of pitching. For idling the test points are on a straight line. This dependence changes under slipstream effect. At high c_a in full-throttle flight a small change in inclination is equivalent to a great lift change, and vice versa at low c_a.

Influence of cut-out in elevator on static elevator effect.- The criterion of the static elevator effect is $\frac{\delta c_m}{\delta \beta}$. It denotes the magnitude of the pitching moment resulting from a 1° elevator displacement. Figures 11 and 12 give the static elevator effect at idling and full throttle for the elevator with and without cut-out against c_a. At low lift, that is, at high speed, the elevator effect is approximately the same for idling as for full throttle. The explanation is that at such flight attitudes the dynamic pressure difference at the control surfaces is small with and without slipstream. At full throttle and increasing lift the elevator effect rises considerably and drops at idling. The elevator effect is as much greater as the ratio: dynamic pressure in the slipstream to dynamic pressure q is greater.

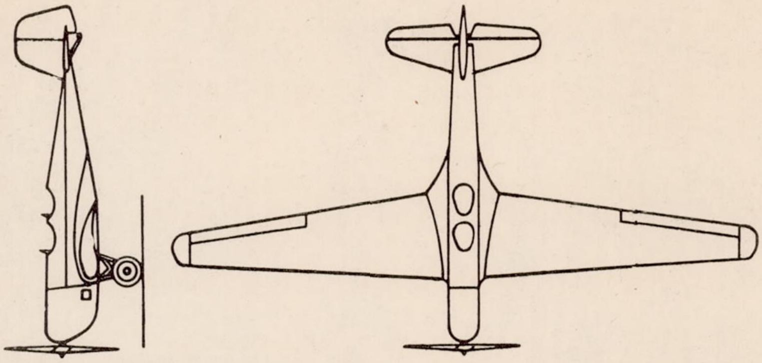
The ratio of elevator effects with and without cut-out is illustrated in figure 13. It averages 0.82 for full throttle, that is, the cut-out vitiates it 18 percent. At idling this detriment depends on the lift; it amounts to about 22 percent for a lift coefficient of $c_a = 0.2$ and drops to 10 percent for $c_a = 1.2$.

REFERENCES

1. Biechteler, C.: Messung des Einflusses des Schraubenstrahls auf den Ausschlag des Seitenruders im Geradeausflug. DVL Yearbook, 1931, pp. 709-11.

2. Hübner, Walter: Flight-Test Data on the Static Fore-and-Aft Stability of Various German Airplanes. T.M. No. 708, N.A.C.A., 1933.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.



Engine performance	$N = 90$ hp.
Wing area	$F = 14.7\ m^2$
Wing span	$b = 11.8$ m
Mean chord	$t_m = 1.34$m
Net weight	$G_R = 380$ kg
Full load (depending on c.g. position)	$G_F = 529$ to 571 kg

Figure 1.- Airplane with modified tail surface.

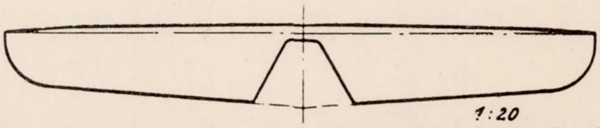


Figure 2.- Outline of original and modified elevator.

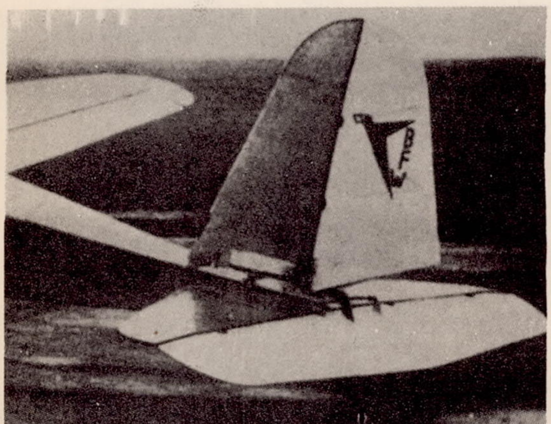


Figure 3.- Original rudder and elevator.

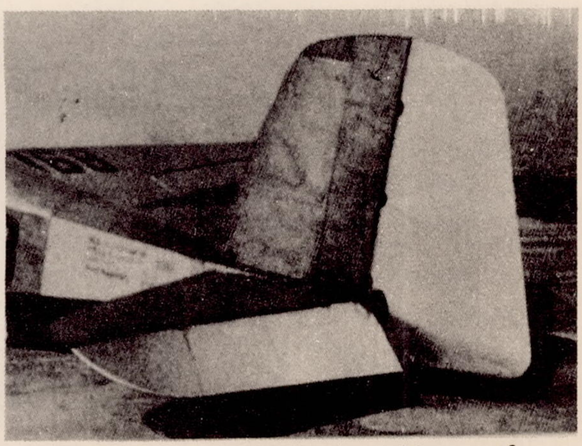


Figure 4.- Modified rudder and elevator.

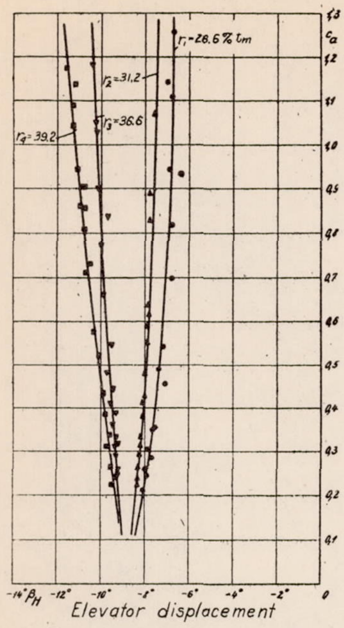
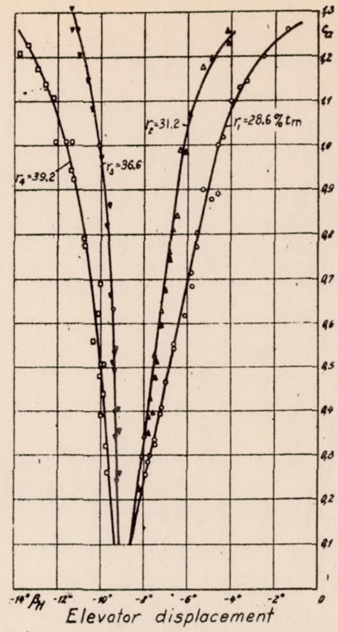


Figure 5.- Elevator displacement versus lift coefficient at full throttle for four c.g. positions.

Figure 6.- Elevator displacement versus lift coefficient at idling for four c.g. positions.



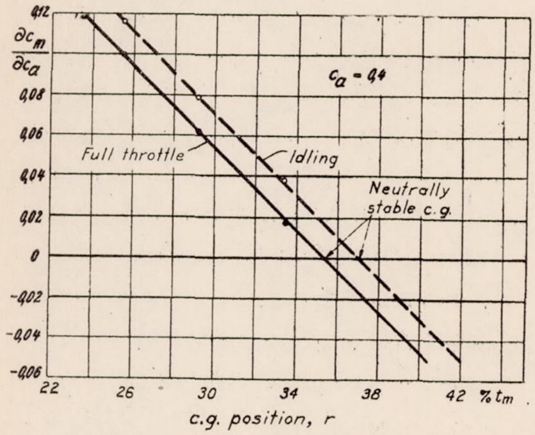


Figure 7a.- $\partial c_m/\partial c_a$ versus c.g. position (original elevator).

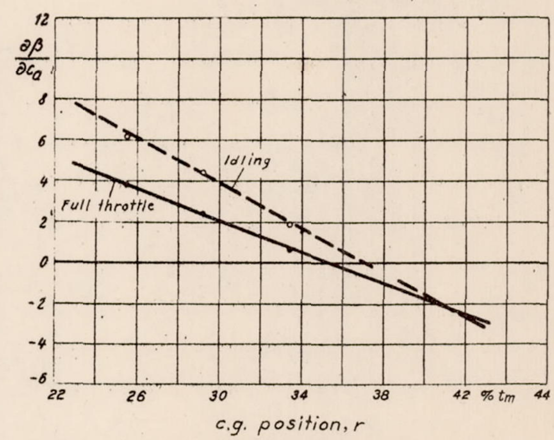


Figure 7b.- $\partial\beta/\partial c_a$ versus c.g. position (original elevator).

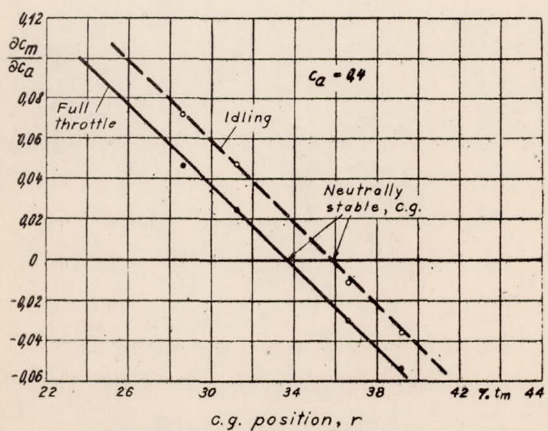


Figure 8a.- $\partial c_m/\partial c_a$ versus c.g. position (elevator with cutout).

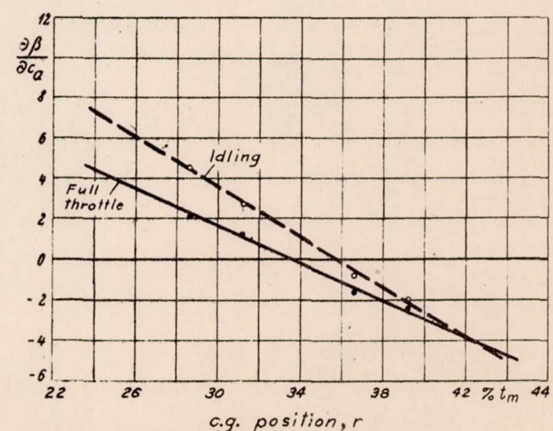


Figure 8b.- $\partial\beta/\partial c_a$ versus c.g. position (elevator with cutout).

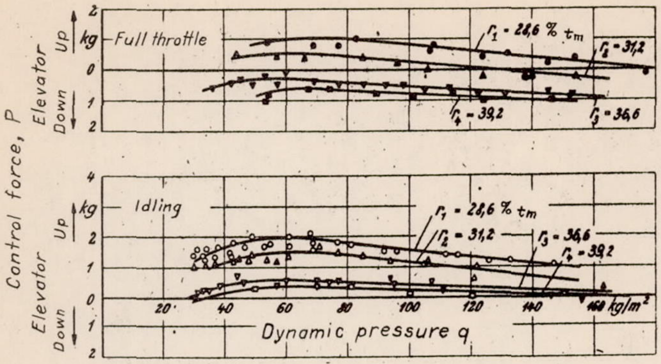


Figure 9.- Control force at idling and full throttle for four different c.g. positions versus q. (elevator with cutout).

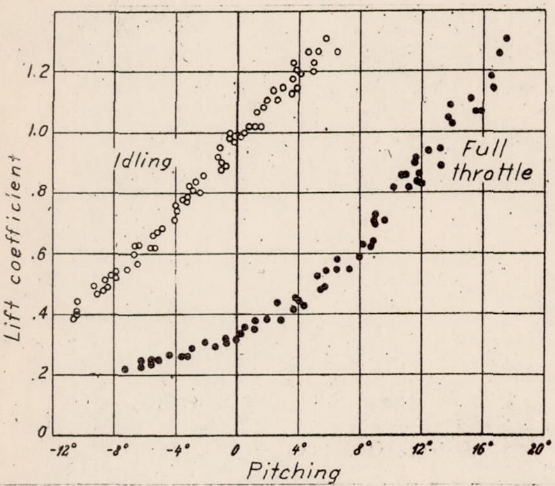


Figure 10.- Lift coefficient versus angle of pitching at idling and full throttle.

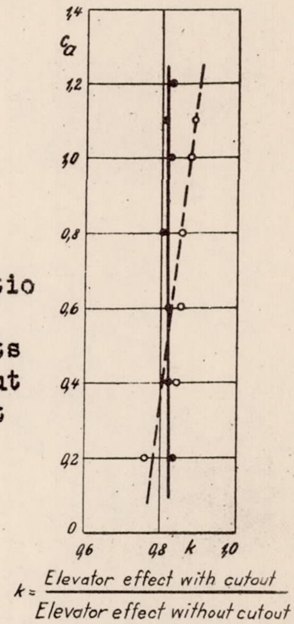


Figure 13.- Ratio of elevator effects with and without elevator cutout versus c_a.

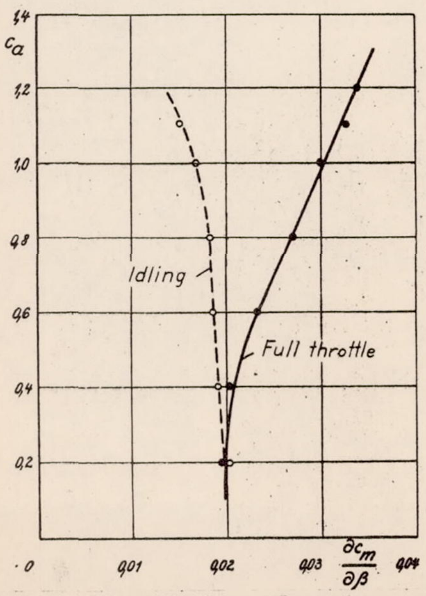


Figure 11.- Static elevator effect with original elevator versus c_a.

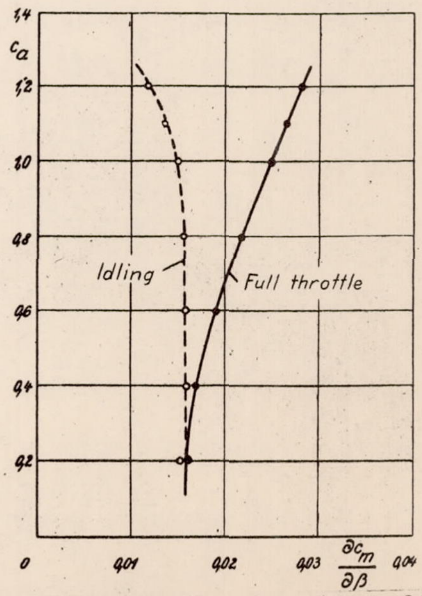


Figure 12.- Static elevator effect with modified elevator versus c_a.